

CLAIMS

1. A method for generating hydrogen, comprising:
providing a hydrogen reactor chamber;
providing a plurality of catalysts within said hydrogen reactor chamber to form a staged catalyst medium, the staged catalyst medium comprising a series of distinct zones or portions, each zone or portion comprising a distinct catalyst or combination thereof having a unique definitive characteristics; and
passing a feed stream of hydrocarbons through the staged catalyst medium to produce hydrogen.
2. The method of claim 1, wherein said plurality of catalysts is comprised of at least one of a high-activity steam reformation catalyst and a coke-resistant steam reformation catalyst.
3. The method of claim 2, wherein said plurality of catalysts is further comprised of a steam reformation catalyst that promotes a water-gas shift reaction.
4. The method of claim 1, further comprising introducing said feed stream of hydrocarbons into said hydrogen reactor chamber.
5. The method of claim 1, wherein said feed stream of hydrocarbons is a fuel having at least one of a C₁-C₄ hydrocarbon or mixture, or a C₁-C₄ oxygenate thereof.
6. The method of claim 1, wherein at least 300 sccm of hydrogen or reformed gas stream is produced in conjunction with residence times of less than about .5 sec.
7. The method of claim 4, wherein said at least one hydrocarbon is propane and provides hydrogen production at residence times of about .15 to about .30 sec and at a temperature of about 575 °C.
8. The method of claim 1, wherein providing a plurality of catalysts within the reactor chamber can be performed by loading said plurality of catalysts within

said hydrogen reactor chamber such that said feed stream of hydrocarbons is exposed to said plurality of catalysts in a predetermined sequential manner.

9. The method of claim 8, further comprising introducing said feed stream of hydrocarbons to a steam reformation catalyst, the reformation catalysts also promoting the water-gas shift reaction, the reformation catalyst located adjacent entrance or exit portions of said hydrogen reactor chamber.

10. The method of claim 1, wherein providing a plurality of catalysts within the reactor chamber can be performed by loading said plurality of catalysts within said hydrogen reactor chamber such that said staged catalyst medium includes a first portion having a steam reformation catalyst, which also promotes the water-gas shift reaction, located adjacent entrance or exit portions and a second portion including at least one of a high-activity steam reformation catalyst and a coke-resistant steam reformation catalyst.

11. The method of claim 2, wherein providing a plurality of catalysts within the reactor chamber can be performed such that the high reforming and water gas shift activity characteristics of at least one catalyst is balanced with resistance to coking.

12. The method of claim 11 wherein said coke-resistant catalyst is loaded at an entrance of the hydrogen reactor chamber, followed by said high-activity catalyst or wherein all or part of the coke-resistant catalyst is mixed with said high-activity catalyst, before loading into the hydrogen reactor chamber.

13. The method of claim 1, further comprising the step of hot swapping of fuels in the C₁-C₄ range to obtain fuel flexibility and uninterrupted production of hydrogen or a reformed gas stream.

14. A hydrogen generation apparatus comprising a reactor chamber wherein a hydrogen generating reaction is performed, the reactor chamber comprising a plurality of catalysts in a staged configuration, wherein the plurality of staged catalysts is provided to form a staged catalyst medium.

15. A hydrogen generating apparatus wherein hydrogen is generated by steam reformation of a hydrocarbon fuel, the apparatus comprising

a steam reformer wherein a reaction resulting in steam reformation of the hydrocarbon fuel is performed, the steam reformer including a portion having a plurality of steam reformation catalysts disposed therein.

16. The hydrogen generating apparatus of claim 15, wherein said plurality of steam reformation catalysts are provided in a staged configuration.

17. The hydrogen generating apparatus of claim 16, wherein said staged configuration includes a coke-resistant steam reformation catalyst loaded at an entrance of said steam reformer.

18. The hydrogen generating apparatus of claim 15, wherein said plurality of steam reformation catalysts includes at least two of a high-activity steam reformation catalyst, a coke-resistant steam reformation catalyst and a steam reformation catalyst which promotes a water-gas shift reaction.

19. The hydrogen generating apparatus of claim 18, wherein said high-activity steam reformation catalyst is a supported nickel-based catalyst.

20. The hydrogen generating apparatus of claim 17 or 18 wherein said coke-resistant steam reformation catalyst is a supported doped nickel-based catalysts.

21. The hydrogen generating apparatus of claim 20, wherein said supported doped nickel-based catalyst is comprised of at least one of calcium oxide, potassium oxide and calcium aluminate or combinations thereof.

22. The hydrogen generating apparatus of claim 21, wherein said supported doped nickel-based catalysts is further comprised of at least one noble metal.

23. The hydrogen generating apparatus of claim 22, wherein said at least one noble metal is at least one of platinum, palladium, rhodium, or ruthenium or any combination thereof.

24. The hydrogen generating apparatus of claim 18, wherein said coke-resistant stream reformation catalyst is loaded at an entrance of said steam reformer, followed by said high-activity steam reformation catalyst.

25. The hydrogen generating apparatus of claim 19, wherein the high activity steam reformation catalyst contains at least one noble metal component.

26. The hydrogen generating apparatus of claim 15, wherein the plurality of catalysts are powders or coatings supported on a substrate.

27. The hydrogen generating apparatus of claim 26, wherein said substrate is selected from the group consisting of foams, monoliths, felts and mesh, or any combination thereof.

28. The hydrogen generation apparatus of claim 15, wherein a fuel cell is in fluid communication with the hydrogen generation reactor.

29. A method for generating hydrogen by steam reformation of a hydrocarbon fuel, the method comprising:

providing a steam reformer; providing a plurality of catalysts within the steam reformer to form a staged catalyst medium; and

passing a hydrocarbon fuel feed stream in the steam reformer to obtain a hydrogen containing reformed stream, the reformed stream is purified to produce hydrogen.

30. A method for manufacturing a hydrogen generation apparatus, the method comprising:

providing an element of the apparatus wherein a reaction associated with hydrogen production is performed; and

providing within said element a plurality of catalysts in a staged catalyst medium, the staged catalyst medium comprising a series of distinct zones or portions, each zone or portion comprising a distinct catalyst or combination thereof.

31. The method of claim 29, wherein purification of the reformer stream is achieved using a hydrogen separation membrane.